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Flush-Deck Nozzles (Navy Type S) for Fire Suppression

Part 1 - Discharge Pattern Studies

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The liquid being discharged through the nozzle plays an important role in determining the final pattern. An Aqueous Film Forming Foam solution may give only half the area of coverage as water through the same device.

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PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

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NAVSHIPSYSCOM Project S4643-12081

FLUSH-DECK NOZZLES (NAVY TYPE S) FOR FIRE SUPPRESSION

Part I - Discharge Pattern Studies

BACKGROUND

Immediately following a severe fire on the flight deck of an aircraft carrier in the summer of 1967, all concerned within the Navy realized that immediate improvements in the area of fire suppression were vitally needed. The first steps involved supplying the ships with mobile equipment dispensing Aqueous Film Forming Foam (AFFF) and P-K-P dry chemical. Concurrent with this step, plans for longer-range installations were being initiated. Also about this time fire extinguishment tests at the Naval Research Laboratory revealed the excellent potentialities of the nuclear-biological-chemical (NBC) wash-down system which was already installed on many of the carriers. The portion of the system of immediate interest from a fire fighting standpoint was the array of nozzles integral with the flight deck which were distributed throughout the flight deck area. They had been designed so as to provide a coverage of water spray over the deck and over aircraft standing on the deck. Although these nozzles did not aspirate air in the manner of a foam-making nozzle and would not generate a fire extinguishing capability on deck fuel spills when supplied with a protein-type foam solution, they would extinguish fires when supplied with AFFF solution. Furthermore, the original rate of solution application per square foot of deck area appeared to be close to being adequate for fire extinguishment purposes. Another attractive possibility with this arrangement existed in its suitability to provide for remote operation.

Preliminary shipboard tests were conducted by NRL and reported in 19[illegible] (1). Subsequently, an order was written for alteration of the NBC wash-down systems on carriers to make them more suitable for a fire suppression system. The basic concept of this alteration was tested under simulated flight deck conditions at Naval Air Station, Jacksonville, Florida (2).

INTRODUCTION

During the tests at Jacksonville (2), it was observed that the wind conditions prevailing at the time of launch and recovery of aircraft from carriers, approximately 30 knots, exerted a strong influence on the fire extinguishing capability of the agents as they were discharged. Nozzle streams from deck-edge nozzles angled upward at 30 degrees were completely ineffective. Only when lowered to a 10 degree angle did they function as intended, but this in turn limited their horizontal range.

In further work involving the flush-deck nozzles under simulated 30-kt winds, it was found that much better fire extinguishing action could be achieved by blocking the center, high-rising jet of solution and diverting all the solution outward in a lower trajectory (3).

As a result of these fire tests, plans were made to study the design of the standard Type S flush-deck nozzle, originally made for water wash-down purposes, to determine how it might be improved as an AFFF application device.

In general, good fire extinguishing action was obtained wherever burning fuel could be covered with falling AFFF spray particles; thus, the reach of the nozzle pattern and the density within the pattern are of prime importance. Of course, setting out to achieve a far-reaching pattern defeats the purpose of maintaining a low profile to minimize wind effects; ultimately, a compromise must be sought. Also, the wind severely distorts all normal discharge patterns (1).

EXPERIMENTAL RESULTS

Apparatus

A modification of NRL's previous procedure for obtaining distribution patterns from the nozzles was made prior to the start of the current series. The patterns for the Type S nozzle with and without the center plug, as reported earlier (3), were made with the nozzle in a fixed position. Much more definitive data were thus produced regarding actual water distribution than the original data taken from the manufacturer (1). The shadow effects of the spider arrangement used to hold the center deflector plate were clearly evident. The newly adopted procedure provided for a 1-rpm rotation of the nozzle while making the timed-discharge runs with collecting-pans along one radial arm. This smoothed out the

"rib-effect" and other irregularities around the horizontal plane of the pattern and resulted in "averaged" values. All runs were conducted indoors to eliminate any influence of wind deflection on the patterns.

Solution Variations

Prior pattern determinations had all been made with water as the liquid, but for this series a water pattern was compared with one obtained using AFFF solution. Immediately it was observed that the type of liquid had a pronounced effect on the resultant pattern. The use of AFFF solution reduced the reach of the output stream dramatically when compared to water and the total area of falling spray coverage was only about one-half. Protein foam solutions were then run and their reach was found to be intermediate to the other liquids. The data presented for some of the nozzles directly compare all three liquids while the other data compare only water and AFFF. It is not anticipated that protein foam would ever be used in the flush-deck nozzles.

Nozzle Variations

In view of the observed effects of liquid type on the spray pattern, additional runs were made with the nozzles used in previous studies (1, 3). The new data for the standard Type S flush-deck nozzle without the center insert are given in Figure 1. The right-hand half of the drawing presents a vertical cross section of the discharge pattern in outline. It shows the center-jet rising to a height of approximately 30 ft, the horizontal reach with water attaining a maximum of 22 ft and the maximum height of the side spray reaching about 4 ft above the deck. The horizontal and vertical reaches of the AFFF and protein solutions may be seen to be reduced in comparison to water.

The left-hand half of Figure 1 shows the application density of liquid falling at varying distances outward from the nozzle. A very high concentration, 0.09 gal/min/ft^2, exists near the center where the falling center plume lands on the deck. This density of application then gradually falls off to zero at the outer limit of reach. The rate of density fall-off appears to be fairly uniform with the exception of a disturbance at a distance about 8 ft from the center. This disturbance occurred with all the liquids, but was most pronounced with the AFFF.

Figure 2 gives data taken in the same manner for the same nozzle, with the center plug in place.

At the Navy's request, the Grinnell Corporation, maker of the Type S nozzle, supplied NRL with two models of the nozzle which had been modified to produce lower discharge trajectories than the original design. The modifications, identified as "A" and "B" in Figure 3, consisted primarily of solid disks over the top of the standard nozzle orifice to deflect the stream outward. The data of Figure 3 summarize the results obtained.

Figure 4 shows the construction details of the "A" modification with its solid, beveled-bottom deflector plate. Figure 5 illustrates the details of the "B" modification with its solid, flat-bottom deflector plate.

Both of the above modifications required removal of the old spider arrangement and installation of a new one. In a shipboard retrofit such a modification could be accomplished without having to remove the nozzle from the deck, but a brazing operation would be necessary.

The NRL approach to the problem was to design a "bolt-on" type deflector plate which could be attached to the nozzle using the same tapped hole as used for holding the center plug. After experimenting with several models, the design shown in Figure 6 was selected. The liquid performance data for this device are given in Figure 7, using the two usual solutions and water.

Another facet of the current investigation was to determine the maximum flow output that could be achieved from the Type S nozzle. The normal 7/16-inch-diameter orifice was bored out to a 3/4-inch diameter, the maximum the wall thickness would permit, which increased its flow from the normal 30 gal/min to 60 gal/min at 30 lb/in.^{2} operating pressure. The resultant patterns with a center plug installed and alternately with a top deflector plate installed are presented in Figures 8 and 9, respectively.

DISCUSSION

Role of the Liquids

The reason for the differences in patterns with the same nozzle using the three liquids has not been definitely established. Two possible explanations have been proposed. One involves the wide variation in surface tension of the three liquids which would have an effect on the stream break-up and the resultant sizes of the droplets formed. Water, with its surface tension of 76 dynes/cm, would

break up into large drops, capable of being propelled. The AFFF solution with a surface tension of 15 dynes/cm would break up into small droplets capable of only short projection. Protein foam solution has an intermediate surface tension value of 30 dynes/cm and an intermediate pattern would be expected.

The second explanation involves the propensity of the liquids toward forming foams. Although the Type S nozzle is not a foam-making nozzle in the sense that it aspirates air into a turbulent liquid jet inside a closed space, the AFFF solution is so surface active that it readily foams when discharged from this nozzle. On the other hand, a water discharge will produce a slight froth. Presumably the bubbles, once formed, with their low density and increased drag would resist projection.

It is entirely possible that the observed pattern differences were caused by a combination of the above two effects. The relation between the two could only be determined by preparing a series of nonfoaming liquids of various surface tensions. It would be difficult to prepare solutions of various foamabilities with a constant surface tension.

Resultant Patterns

The data of Figure 1, representing the performance of the Type S nozzles as presently operating on board carriers, show the variation in density of liquid falling within the pattern as a function of distance from the outlet orifice. The ideal distribution, of course, would be a uniform density from the center all the way to the outer perimeter. The high concentration observed at the very center is undesirable because it means that this liquid must spread horizontally over the deck for considerable distances in order to consolidate with agent from adjacent nozzles. In addition, the high rising plume has been found to be subject to wind and thermal losses. During the discharge of water, the gross pattern coverage is a circle 44 ft in diameter which is an area of 1500 ft^2; thus, the average overall application rate within the pattern is 0.020 $gal/min/ft^2$ although wide local variations occur. In the many areas of the flight deck where the installed nozzle spacing is 20 ft by 40 ft, this reach would barely provide falling liquid over all of the deck surface under no-wind conditions.

When discharging AFFF, the diameter of the pattern contracts to a diameter of 34 ft giving an area of 907 ft^2 and an overall

application rate of 0.033 gal/min/ft^2. In this case the 20-by-40 ft nozzle spacing would leave many "holidays" or areas not covered by a falling spray of agent.

Insertion of the center plug had the immediate effect of not only decreasing the maximum application density occurring within the pattern from 0.075 to 0.045 gal/min/ft^2 but also moving the area of maximum concentration outward from dead center to 12 ft. The maximum reach or radius of the pattern increased only slightly, from 17 to 19 ft by use of the center plug with AFFF solution. The maximum height any liquid reached was 4 ft above the deck. The total area of coverage with falling AFFF spray is exactly half the total area of water coverage.

Examination of Figure 3 reveals that Grinnell engineers accomplished their objective of producing a low-silhouette discharge with the stream of the "A" model rising to only 18 inches above the deck and the "B" model to 12 inches. In doing so, however, the outputs were highly concentrated close-in to the nozzle and the maximum range was reduced in a manner proportional to their trajectory height. The "B" nozzle exhibited a peculiar characteristic in that is tended to operate in two different modes, each producing different patterns. The switch from one mode to the other and back again seemed to follow a random pattern and with no apparent reason. It is believed that the data given in Figure 3 are the best overall representation.

NRL's "piggy-back" deflector produced a pattern, Figure 7, quite similar to Grinnell's "A" modification. Both peaked at application densities of about 0.10 gal/min/ft^2 but NRL's peaked about 2 ft farther out and gave a total area pattern coverage almost 50 percent greater. The highest point of its stream trajectory was 24 inches. In addition to the NRL design being easier to retrofit in the field, it offers another advantage by providing a means of direct access to the orifice for cleaning by rodding, reaming, or drilling in the event it becomes clogged by surface debris or foreign material in the piping.

By comparing Figures 2 and 8, the results of doubling the flow output from 30 to 60 gal/min with the center plug inserted can be determined. The peak density with the AFFF solution rose from 0.045 to 0.075 gal/min/ft^2, but was moved outward only slightly. The outside pattern diameter increased from 38 to 42 ft. By comparing Figures 7 and 9, the results of doubling the flow output with a top deflector plate can be determined. The peak density with the AFFF solution rose from 0.092 to 0.102 gal/min/ft^2 and the

peak density area was moved out radially from 8 to 12.5 ft. The diameter of the circular pattern area increased from 30 to 36 ft.

From the above results it can be seen that greatly increasing the flow rate per nozzle does not provide very much in the way of increased pattern coverage by falling spray, although it would increase the overall average application rate. Any additional flow through each nozzle would result in increasing friction losses and lowered nozzle pressures unless the diameters of the piping were enlarged. Possibly this could be offset with the existing piping by using drag reducing agent but the problem of fire pump capacity would still be a controlling factor.

The data for the NRL deflector plate, Figure 7, shows that the spray trajectory height was reduced to 24 inches from the 48 inches found using the center plug only, (Figure 2). This apparent benefit, however, was offset by concentrating the spray at a point closer in and shrinking the maximum reach of spray from 19 ft to 15 ft.

Center Plug Installation on Shipboard

An instruction has been sent by NAVSHIPSYSCOM to COMNAVAIRLANT and COMNAVAIRPAC (4) requesting installation of the center plug in all Type S flush-deck nozzles. The standard plug is a 3/8-16 threaded, headless set-screw with a cone-shaped bottom tip. The lack of a head on this screw makes it difficult to locate it during installation and the lack of a method for locking it in place makes it subject to loosening due to vibration of the deck. Proper location of the screw is important because of its influence on the spray pattern produced. The normal position, shown on the left in Figure 10, is with the top of the screw flush with the center deflector plate; this is the setting with which all fire tests and pattern measurements have been made. The center view and right-hand view of Figure 10 show alternate positions of the screw being too high and too low.

Consideration should be given to a cap-type screw, which when screwed tight would locate the bottom of the tip properly and would provide a means of locking the screw in place.

Future Tests

The above tests describe the performance of the Type S nozzle under no-wind conditions only, a situation which will normally not exist during fire extinguishing operations on board ship. Additional performance studies under wind speeds up to 30 knots should be made.

Actual fire extinguishing tests will be required on the various nozzle patterns, with and without wind, to establish definitely the optimum relationship between spray height and spray reach.

Another factor to be investigated in fire tests will be the isolation of the effects of covering the nozzle with appreciable depths of fuel and water, an unnatural condition created during the large scale CASS tests performed at NWC, China Lake, and in fact most fire tests, by diking the fire area. Water is often used as a substrate in fire testing on nonsurfaced terrain both to prevent seepage of fuel into the ground and to overcome unevenness in paved areas, and to present a continuous, unbroken fuel surface. In the case of protein foams, discharge from beneath a water layer has been found to be very destructive to the foam, but this particular point has not been looked into in the case of AFFF. Fuel sometimes covers the flushdeck nozzle to the depth of an inch in ponded situations, and the contribution of fuel being drawn up into the AFFF discharge to create a potential flame-thrower has not been studied specifically. (The fact that the flush-deck nozzles in the China Lake CASS tests and previous evaluations were covered with water and/or fuel did not interfere with their satisfactory fire extinguishment performance. However, it is desired to learn if nonponded conditions, like those during a shipboard fire, will enhance the performance.)

Finally, the presence of fire alone appears to influence the spray patterns produced by the nozzles aside from the effects of wind currents external to the fire area.

Fire tests using foam making devices other than the present flush-deck nozzle are needed to determine the physical properties of the optimum AFFF solution. Once this is done, steps can be taken to design a new flush mounting device to generate this optimum foam for future ship construction.

CONCLUSIONS

The high trajectory liquid spray produced by the Type S flush-deck nozzle (as presently installed on aircraft carrier flight decks) can be redirected toward a lower, wider reaching pattern through the installation of a center plug or through the modification of the deflector plate.

The maximum pattern reach obtainable and the largest area of coverage by the pattern of falling spray are direct functions of the trajectory height. Large patterns cannot be achieved with low trajectories.

Pattern dimensions depend on the surface tension and/or foamability of the liquid being discharged. Areas of falling AFFF spray may be less than half the area for water from the same nozzle. AFFF sprays tend to concentrate in certain areas and are not as evenly distributed throughout the whole pattern area as water sprays are.

A modification involving a screw-on device for lowering the spray trajectory from the Type S flush-deck nozzle would provide easier installation and easier orifice cleaning than a solid deflector plate modification would.

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The authors express their thanks to Mr. J. W. Porter for his faithful assistance in making the many required measurements.

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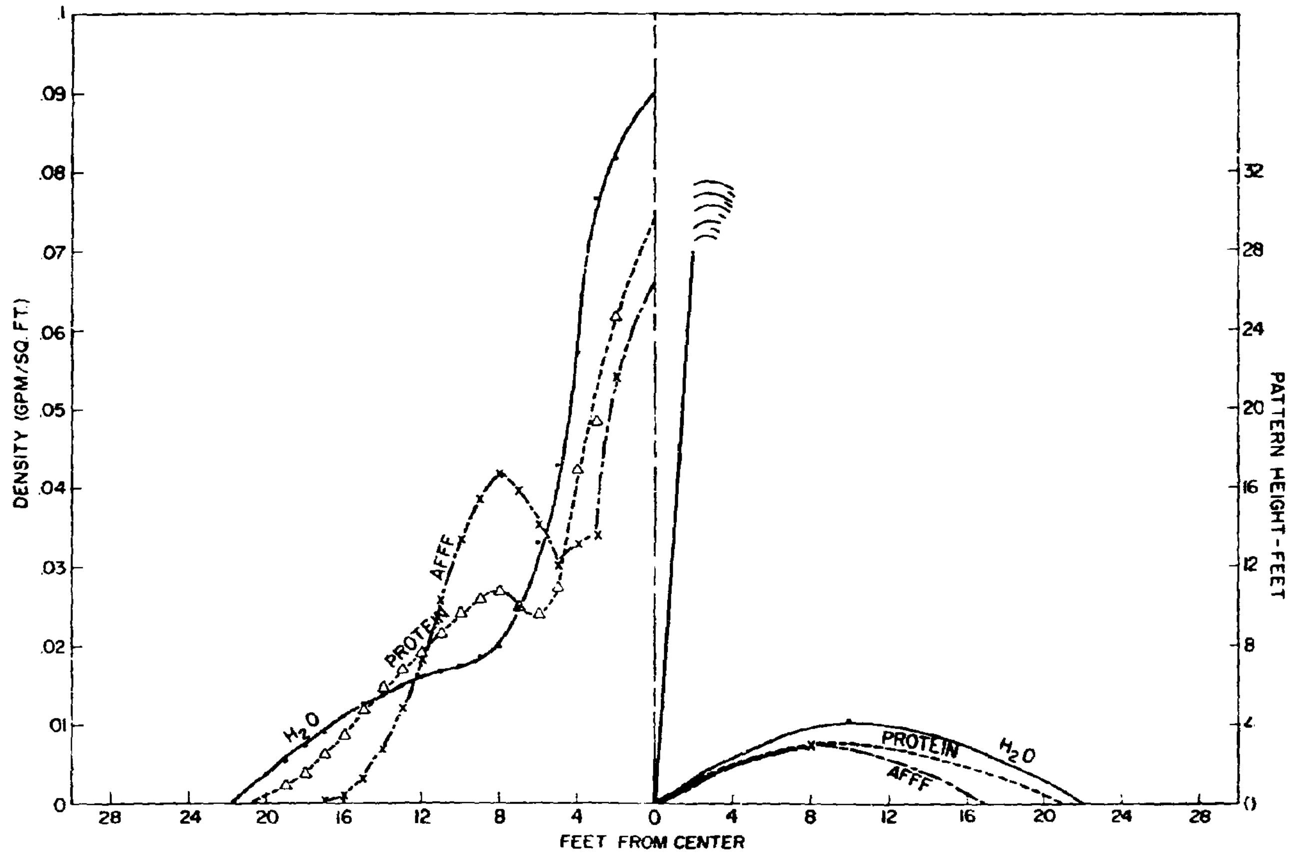

Fig. 1 - Type S Flush-Deck Nozzle Performance Data (With Center-Plug Removed) Showing Vertical Cross-Section of Discharge Pattern and Ground Distribution Pattern While Operating With Water, AFFF, and Protein Foam Solution

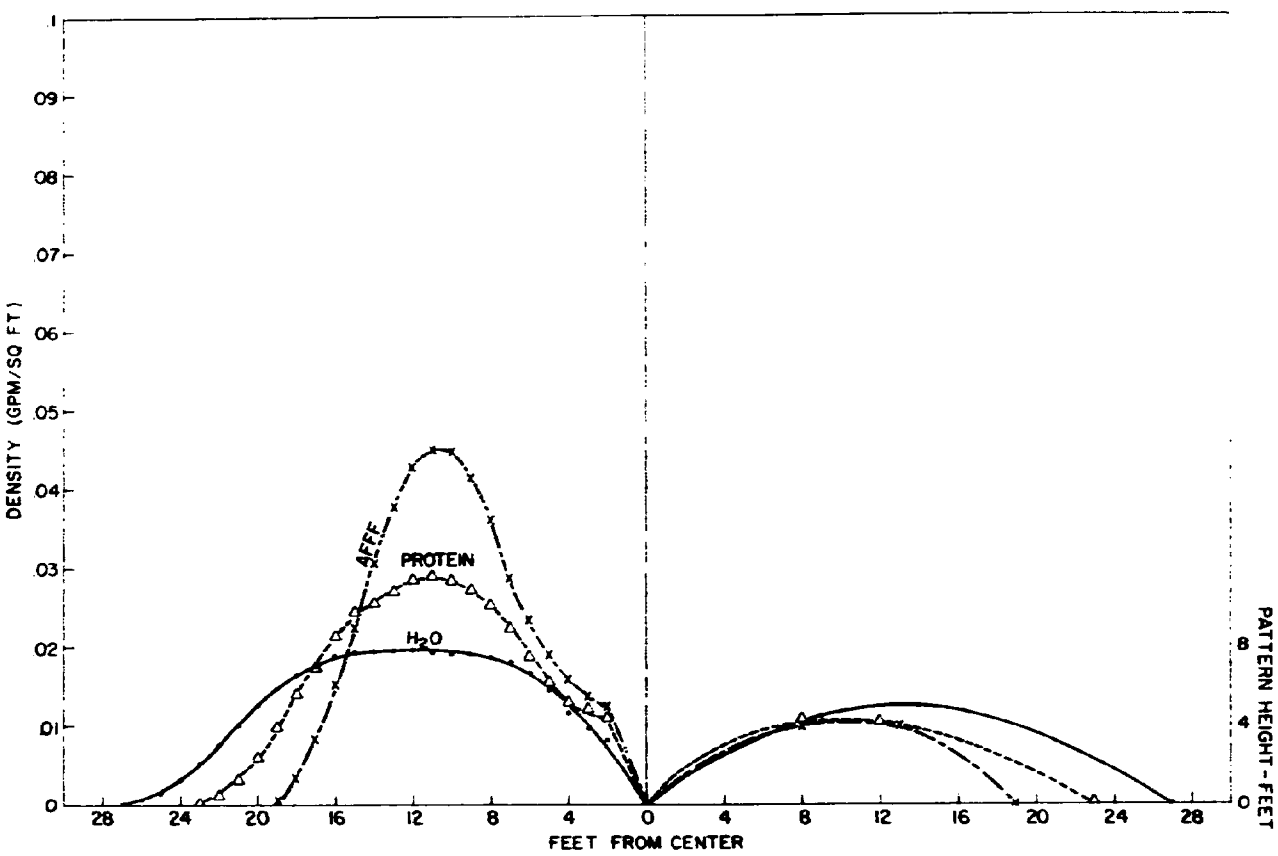

Fig. 2 - Type S Flush-Deck Nozzle Performance Data (With Center-Plug in Place) Showing Vertical Cross-Section of Discharge Pattern and Ground Distribution Pattern While Operating With Water, AFFF, and Protein Foam Solution

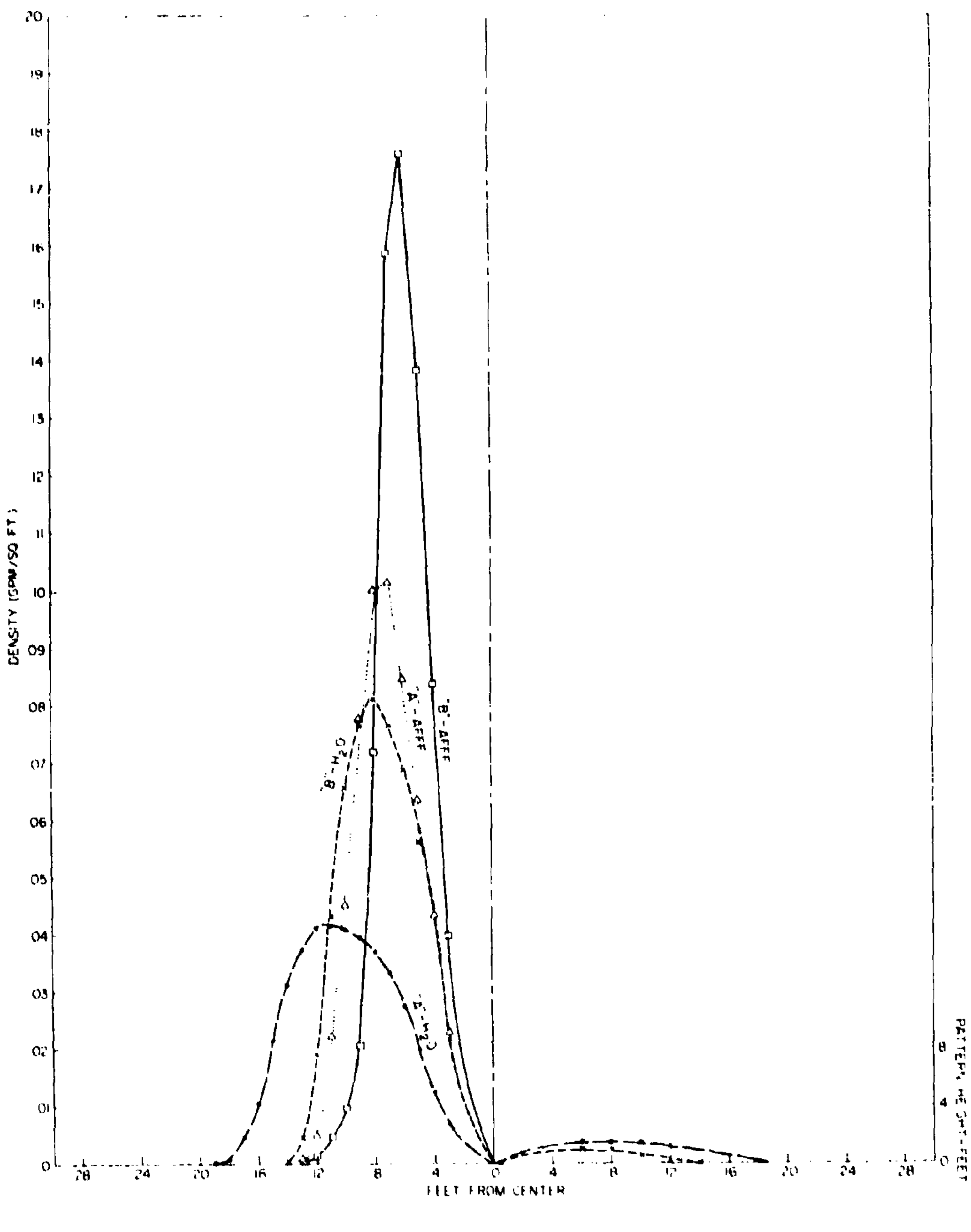

Fig. 3 - Data for "A" and "B" Modifications of the Type S Nozzle as Supplied by the Grinnell Company

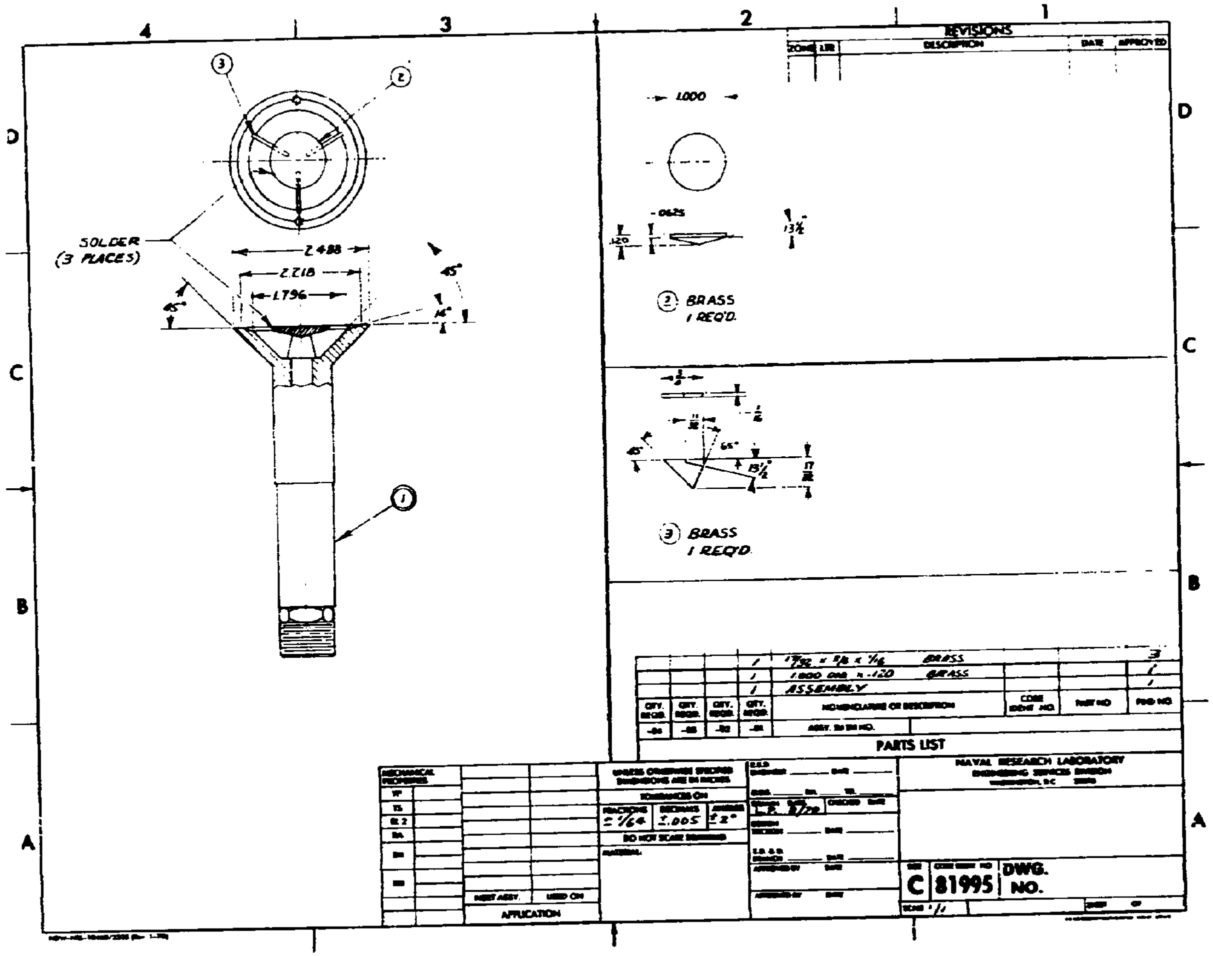

Fig. 4 - Construction Details of Grinnell's "A" Modification

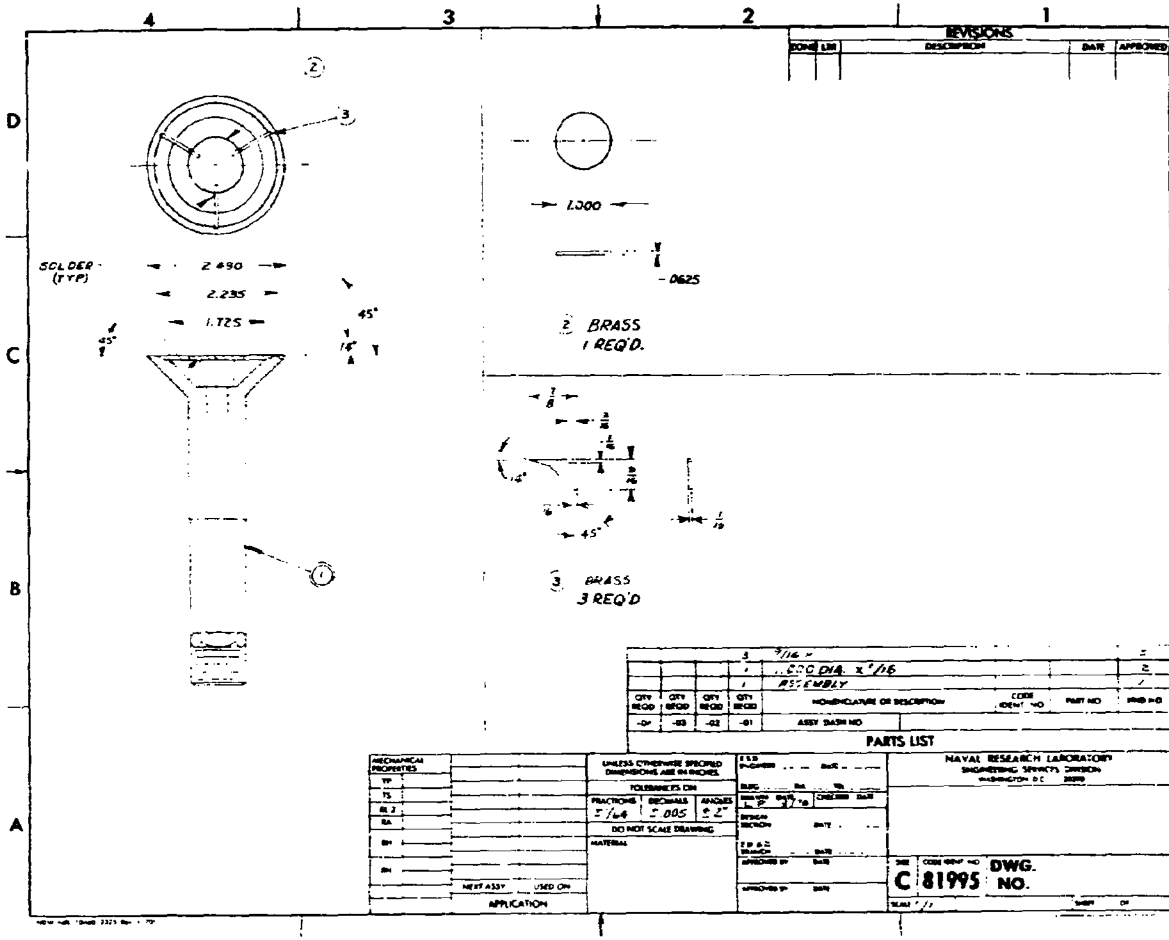

Fig. 5 - Construction Details of Grinnell's "B" Modification

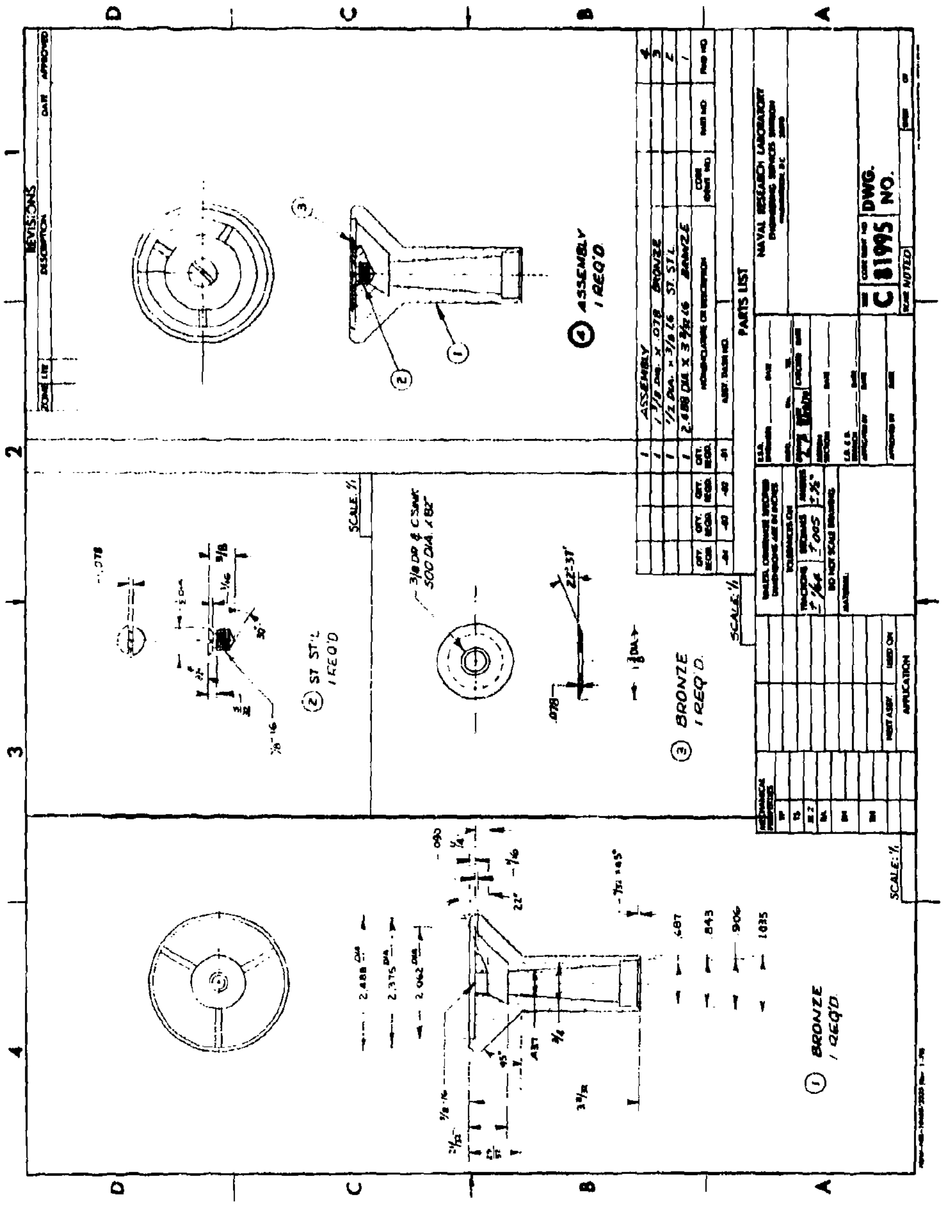

Fig. 6 - Construction Details of NRL "Add-on" Modification

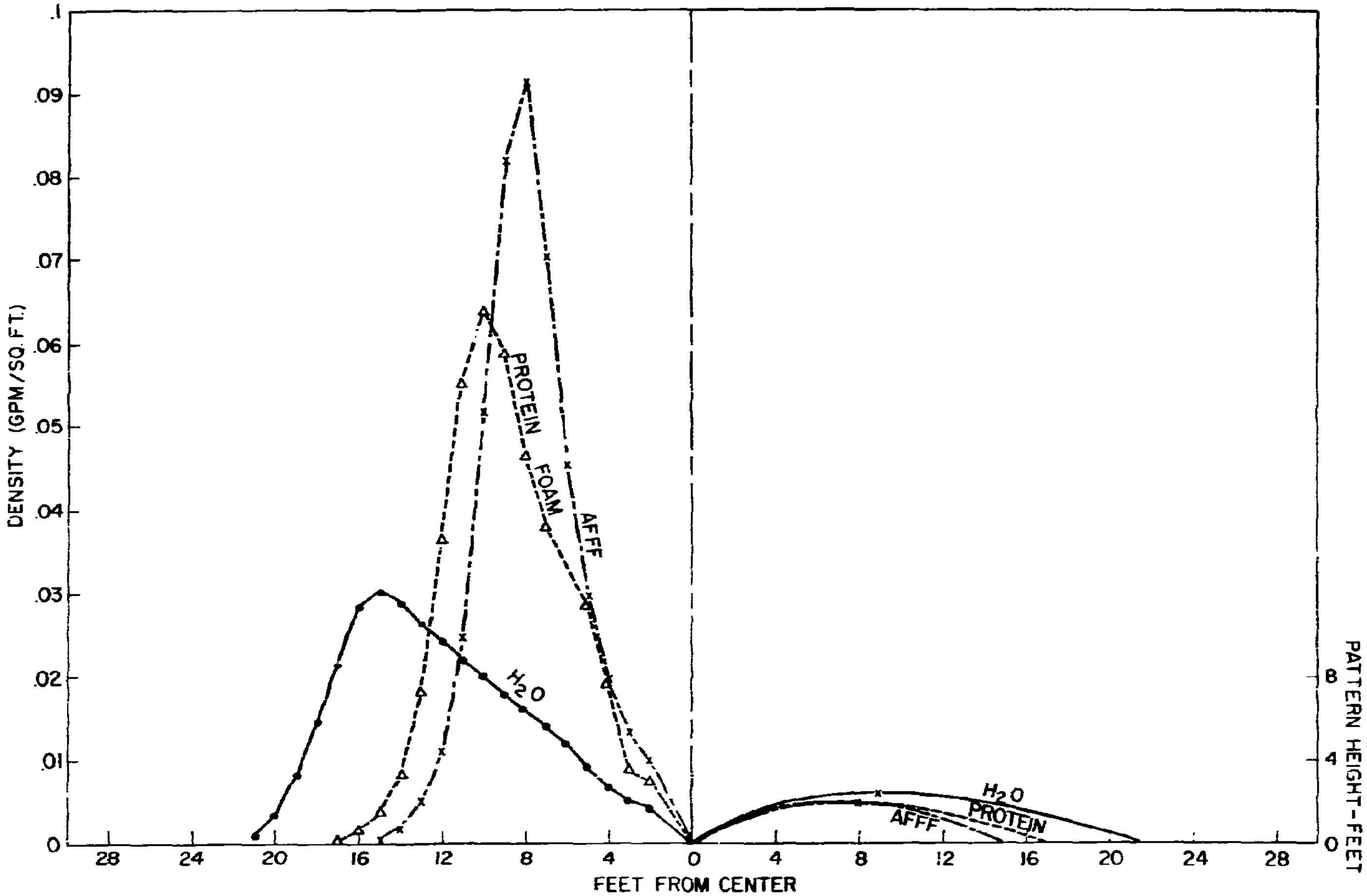

Fig. 7 - Type S Flush-Deck Nozzle Performance Data with NRL "Add-On" Deflector Plate Attached

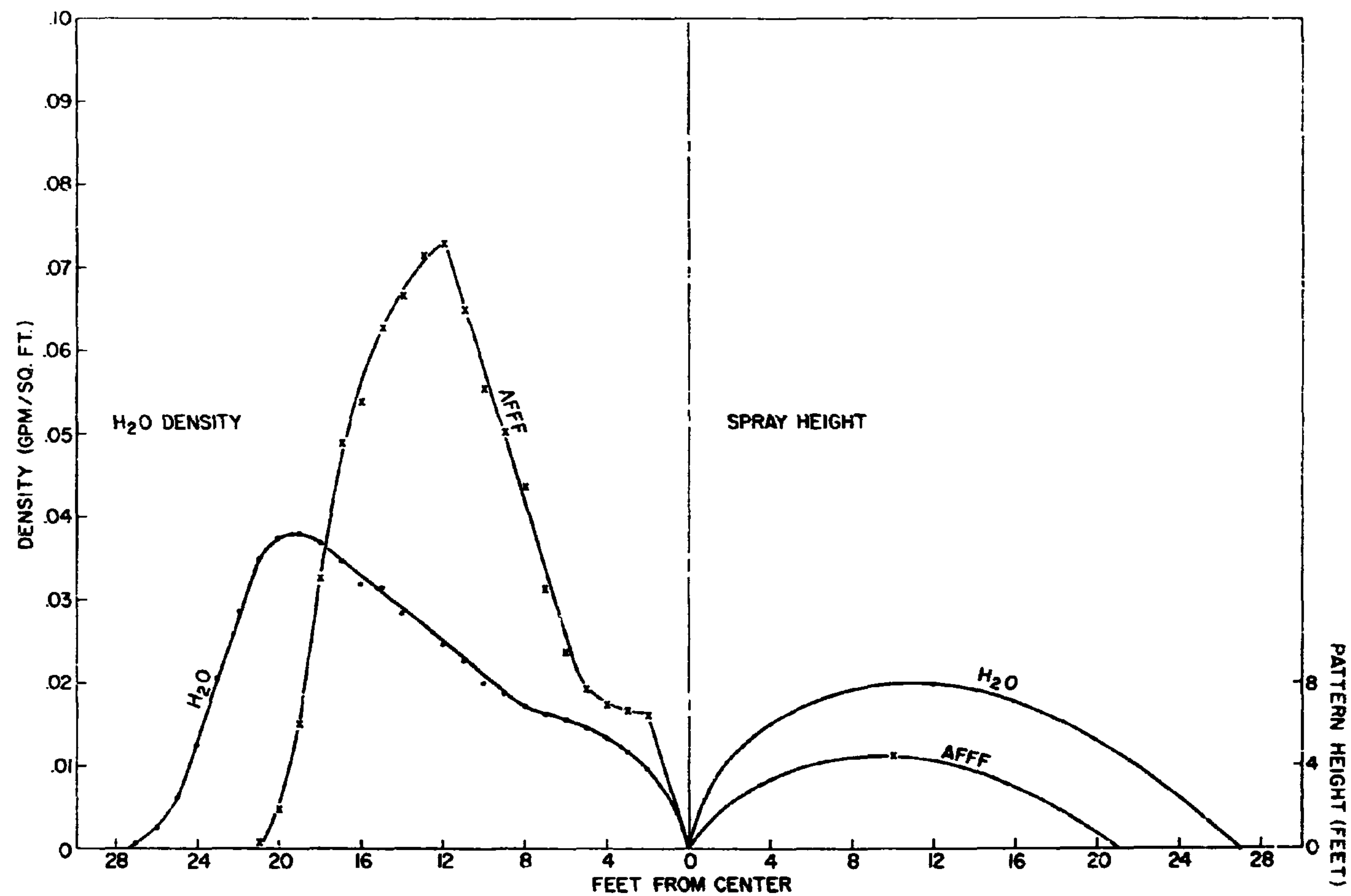

Fig. 8 - Type S Flush-Deck Nozzle Performance Data with Center-Plug Inserted After Boring Orifice to 3/4-inch Diameter

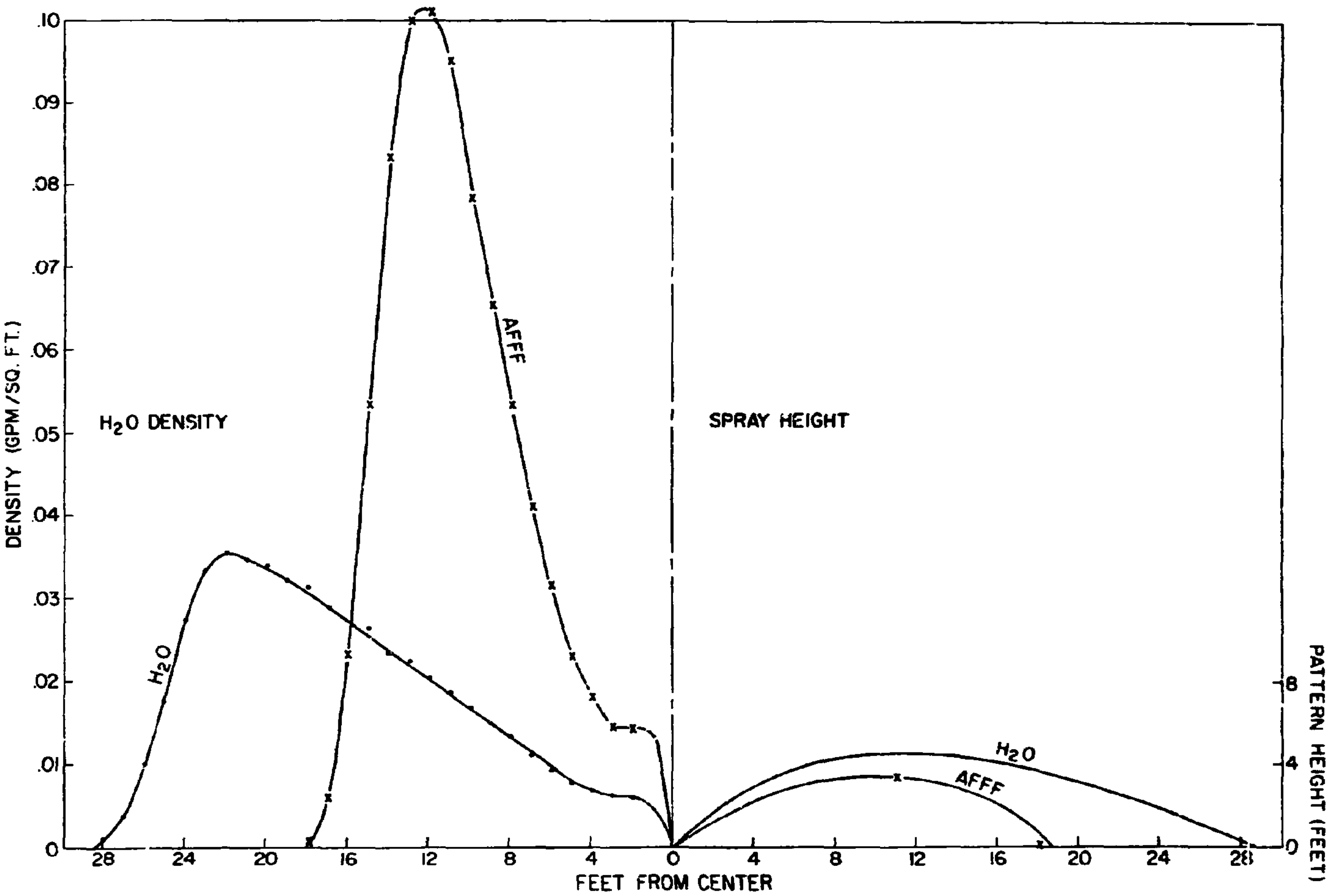

Fig. 9 - Type S Flush-Deck Nozzle Performance Data with Deflector Plate Attached After Boring Orifice to 3/4-inch Diameter

Fig. 10 - Cross-Sectional Views of Type S Nozzle With Center-Plug in Place. Left-Hand View Shows Proper Location of Plug; Center View Shows Plug Too Far In; Right-Hand View Shows Plug Too Far Out